arkoses which have been converted into mica-schists. The change of feldspars into biotite and quartz is notable.

The eruptive rocks cutting the Penokee series in the form of dikes and sheets are normal diabases, occasionally grading into gabbro. The chief feature of interest developed in their study is the fact that their freshness and alteration is closely dependent on the permeability of the adjacent rocks to percolating waters, showing that environment may be a more important element than age in the preservation of a rock.

The formations composing the Eastern area of the Penokee series have been modified by contemporaneous volcanic action, and the accumulation of surficial lavas, both massive and fragmental. These were of a basic character, some being porphyrites, others diabases, grading into gabbros that are considered to be deep-seated parts of the lavas. These rocks have been altered into greenstones. The other rocks of the Eastern area resemble those of the Western area in petrographical characters.

In the closing chapter of the monograph the flexures and faults are discussed, and the structure of the region is described. The Penokee series is correlated with the Animikie series, and also with the Marquette. Other correlations are suggested.

JOSEPH P. IDDINGS.

Summary of Current pre-Cambrian North American Literature.[1]

Cross[2] describes intrusive sandstone dikes in the Pike's Peak granite. The material has all the characteristics of dikes. The larger number are a few inches or a few feet thick, but they vary from a film to those three hundred yards wide. Some of the larger have been followed for nearly a mile. The dykes have a general trend parallel to the belt in which they occur, and they are connected in an intricate way by diagonal fissures, and all are regarded as belonging to a single fissure system. The material of the dikes is fine and even-grained sand grains, either in the form of sandstone or more commonly indurated to a dense hard quartzite. The induration is mainly due to limonite, but in some degree is due to muscovite, and to secondary silica. The

[1] Continued from p. 454, Vol. II. JOURNAL GEOLOGY.

[2] Intrusive Sandstone Dikes in Granite, by WHITMAN CROSS. Bull. Geol. Soc. Am., Vol. 5, pp. 225–230, pl. 8, 1894.

physical and mechanical facts seem to show that the fissures of this complex were filled by fine quicksand, injected from an unknown source, containing a large amount of homogeneous material.

Peale[1] places the Belt formation of the Three Forks sheet in the Algonkian. This formation at the East Gallitan River is 2300 feet thick and consists of an alternation of coarse, micaceous sandstones and conglomerates, with beds of hard argillaceous slates, and bands of thin-bedded, dark blue, siliceous limestones. The latter are very hard and some are slightly magnesian. The limestones occur mainly towards the base of the section, in bands ordinarily from five to twenty feet in thickness, but sometimes reaching nearly fifty feet. On the Bridger range the formation has a thickness of at least 6000 feet. It is also characteristically exposed in the Cañon of Jefferson River fourteen or fifteen miles above its mouth.

Nowhere in the Gallitan valley is the belt formation found in immediate superposition upon the Archean, but that it is post-Archean is shown by its being made up largely of Archean débris. Between the Belt formation and the overlying Flat Head Cambrian quartzite there is no well defined unconformity, although there was an important orographic movement between the two, the entire area of the Three Forks sheet being submerged at this time. Little, if any, induration is seen in the Flathead formation, while the Belt beds are so altered in most cases as to resemble closely the metamorphic crystalline rocks which underlie them, and from which they were derived by their breaking down. Notwithstanding the metamorphism there is no mistaking the sedimentary character of the Belt formation.

We have, therefore, a non-fossiliferous formation of clastic beds, in some places highly metamorphosed, which lies between the Archean gneisses and a belt of quartzite, above which are beds with Middle Cambrian fossils. From its stratigraphical position this formation can be only of Lower Cambrian or of Algonkian age.

The possibility that Lower Cambrian fossils may yet be found in the quartzite at the base of the Flathead formation; the absence of organic remains in the Belt formation; the metamorphosed condition of the latter, and the existence of an orographic movement between the quartzite and the beds below lead us to refer the latter, for the present at least, to the Algonkian.

[1] The Palæozoic Section in the Vicinity of Three Forks, Montana, by A. C. PEALE. Bull. 110, U. S. G. S., 1893, pp. 56.

McConnel[1] reports a small area of Archean gneisses on the northern shore and neighboring islands of Lake Athabasca, on the islands of Lake Mammawi, and in the tilted deposits bordering Quatre Fourchés River. The gneisses include hornblendic, micaceous, chloritic and epidotic varieties. In places they pass into a mica-schist or chlorite-schist. The gneisses strike from 10° to 20° west of north.

Bell[2] describes the pre-Palæozoic rocks of the north of Lake Huron as having been subjected in certain areas to vast denudation and decay before Palæozoic time. The evidence of this decay, most frequently found in granite, consists in hollows, pits, irregular ridges, and even small caverns, which are filled with Palæozoic limestone. These irregularities are regarded as having been formed at the bottom of the deep sea by solution. Had the erosion taken place on land there would be evidence of this in deeper decay in the substances of the rock and in the deposition of detrital deposits below the pure limestone, which in many cases rests directly upon the pre-Palæozoic rocks.

In the area between the foot of Lake Ontario and the head of Georgian Bay the contact of the Potsdam sandstone and Black River limestones with the underlying gneiss and quartzite is seen at many localities. These rocks are generally hard and fresh. The surface is irregular, and the whole has been buried beneath the horizontal Palæozoic rocks.

Many of the long narrow valleys of the Archean region are due to the decay and removal of wide greenstone dikes or parallel dikes, with the belts of rock between them. The greenstone dikes are never found to traverse the overlying Silurian, and it is supposed that these valleys were mostly formed before the deposition of the Palæozoic strata. It is thought that the larger part of this Archean area never received any of the Palæozoic rocks upon it, and that the surface of the Archean had been reduced to something like its present level and aspect before the Palæozoic deposits were deposited. As evidence of this are outliers of the Potsdam sandstone and Black river limestone filling similar narrow valleys.

Comments. It may be suggested that the evidence given that the

[1] Report on a Portion of the District of Athabasca, comprising the Country between Peace River and Athabasca River, North of Lesser Slave Lake, by R. G. McConnell. Ann. Rep. Geol. Sur. of Canada for 1890–1, Vol. V, Part 1, D, pp. 5–62, 1893.

[2] Pre-Palæozoic Decay of Crystalline Rocks North of Lake Huron. Bull. Geol. Soc. Am., Vol. 5, pp. 357–366, pls. 15, 16, 1864.

greater part of the Archean area was never covered by Palæozoic rocks is inconclusive, since it is stated that the pre-Palæozoic topography of the area covered by Palæozoic rocks is the same as that not so covered.

Adams[1] gives a preliminary description of Sheet 118 of the Canadian Survey, an area of about 3500 square miles, situated north of Lake Ontario, in the counties of Victoria, Peterborough and Hastings. The whole area is occupied by the rocks of the Laurentian system, with the exception of the southeast corner, which is underlain in part by the Hastings series. In the surrounding eastern portions there is an abundance of crystalline limestone, and the rocks have all the characteristics of the Grenville series of Sir William Logan. In the northwestern part of the area the country is apparently occupied by gneiss alone. The relations of the Grenville series to the gneiss free from limestone has not yet been definitely determined, although the limestone and the associated gneiss seem in certain cases to partially enclose areas which contain no limestone. Throughout the area occupied by the Laurentian rocks, the dip, are uniformly at an easterly direction, usually at moderate angles. Only at one or two points have westerly dips been observed, and these are quite local. The relations of the Hastings series to the Laurentian is also as yet uncertain. One of the most marked characteristics of this district is the great development of pyroxenic and hornblendic rocks, among which many are, without doubt, of eruptive origin. Also there are several large intrusive masses of granite, and a very extensive mass of nepheline syenite. Otherwise the Hastings and Grenville series are not very unlike petrographically.

In the area south of Sheet 118, in Dalton and the western part of Digby townships, is found reddish orthoclase gneiss, with dark, micaceous and hornblendic bands, which is cut in a complicated way by coarse-grained granite. In the eastern part of Digby township and in Lutterworth and Galway townships are found crystalline limestones, and the peculiar rusty weathering gneisses always associated with them. In the limestone districts various metalliferous ores are found.

[1] Preliminary Report on the Geology of a Portion of Central Ontario situated in the Counties of Victoria, Peterborough and Hastings, together with the results of an Examination of Certain Ore Deposits Occurring in that Region, by F. D. Adams. Geol. Sur. of Can., Ann. Rep., Part I., Vol. VI., pp. 15, 1894.

Low[1] describes the Archean of Portneuf, Quebec and Montmorency counties in Quebec. These rocks cover about 980 square miles, and are covered on the south by Cambro-Silurian limestones and shales. A rough section from west to east across the northern portion at right angles to the strike through lake Simon is as follows:

(1) Dark schistose mica-gneiss, interbanded with coarser red and gray mica-gneisses. 10 miles.
(2) Fine-banded gray, pink and red mica-gneisses, and mica-hornblende-gneisses. 10 miles.
(3) Dark gray garnetiferous hornblende-gneiss. 2 miles.
(4) Fine-banded gray, pink and red mica-gneisses and mica-hornblende-gneisses. 7½ miles.
(5) Dark green basic, crushed granitic gneiss. 1½ miles.
(6) Coarse red and gray augen-gneiss. 2½ miles.
(7) Fine-banded gneiss (2) and (4). 6 miles.
(8) Coarse red and gray augen-gneiss. 6 miles.
(9) Fine-banded gray and pink mica-gneiss. 14 miles.
(10) Anorthosite. 2 miles.
(11) Fine-banded, gray and pink gneisses. 12 miles.

In this section the rocks are grouped in accordance with the predominating kind, although bands of other varieties are included in all of the rough divisions. Divisions 1, 2, 3, 4, 9 and 11 appear to have been originally clastic rocks, subsequently completely metamorphosed into schists and gneisses, and subjected to great pressures, which have folded and twisted them so that their original horizontal succession is greatly obscured. The different bands are conformable and appear to grade into one another. The 5th division embraces rocks probably of igneous origin, which have been injected along a line of weakness between the banded gneisses and the coarser-grained rocks of the 6th division. The 6th and 8th divisions are usually gneissic, but often are granitic. They appear to underlie the banded gneisses, and are either the remains of older beds that have been re-fused or are original molten matter which has dissolved and floated portions of the banded beds, since fragments of them are enclosed in the coarser gneisses. The anorthosite is also igneous, having apparently been intruded in its present position after the formation of the banded gneiss with which

[1] Report on the Geology and Economic Minerals of the Southern Portion of Portneuf, Quebec and Montmorency Counties, Province of Quebec, by A. B. Low. Ann. Rep. Geol. Sur. of Canada for 1890–91, Vol. V., Part 1, L, pp. 5–82, 1892.

it is in contact. This contact is not sharp in places, as the gneisses usually seem to have been infiltrated by basic feldspar material from the anorthosite, causing a gradual passage from one to the other. At one place in division 11 appears a band of highly crystalline limestone.

At many places the Trenton limestone is found directly in contact with the Archean rocks. The surface of the Archean rocks on which these newer beds were laid down had a rounded undulatory form, closely resembling the present exposed surface. The gneisses and the limestone present fresh, undecomposed surfaces. At various places between the Trenton limestone and the Archean is a thin layer of calcareous sandrock, resting in the hollows of the Archean surface, which holds Trenton fossils. In one place in the limestone is found a bowlder of gneiss six feet long, four feet wide and four feet thick, which is supposed to have been dropped by floating ice.

Mathew, W. D.[1] describes the pre-Cambrian area near St. John, New Brunswick. The earliest series, or Laurentian, consists chiefly of granitic and gneissoid rocks, limestones and quartzite, the two latter being confined to the upper beds. The strata lie steeply inclined in a succession of ridges and folds striking in a general northeast and southwest direction. Overlying this more crystalline series, generally at a lower dip, are fine-grained flinty rocks, interbedded with various schists, porphyries, ash-rocks and sandstones, and with great masses and dikes of trap. These have been called Huronian.

The old part of the Laurentian consists of gneisses proper, accompanied by hornblende-schists and mica-schists, which in thin section show no trace of igneous origin, and of limestone and quartzite. Associated with the less crystalline limestones are beds of fine-grained black rock, which has generally been called argillite. Much of the Lower Laurentian series consists of granite, diorite and gabbro, which are igneous rocks. The granite intrudes both the gabbro and the sedimentary series as is shown by contact effects and by veins and pegmatite masses adjacent to the granite in the sedimentary series. As to the age of this intrusion, it may be as late as Devonian, but as the granite is cut by innumerable dikes which also cut the Huronian and the Palæozoic, it is very likely that the intrusion is pre-Huronian. The great unconformity in the district is between the Laurentian and Huronian, not between the Huronian and Cambrian.

[1] The Intrusive Rocks near St. John, New Brunswick, by W. D. MATHEW. Trans. N. Y. Acad. Sci., Vol. XIII., pp. 185–203, 1894.

Ells[1] states that the mica and biotite of the Laurentian of Canada is confined to a horizon composed of a series of gneisses of the upper portion of the Laurentian, siliceous rocks which underlie the limestone proper. This horizon graduates upward by regular passage through the interstratification of calcareous layers into the massive crystalline limestone formation.

Whittle[2] describes the main axis of the Green Mountains as a series of sharp, compressed folds striking approximately north and south and overturned to the west in most localities so that induced schistosity and stratification dip eastward. Localities on the western border have a steep westerly dip in many instances; in others the border series as a whole is nearly in a vertical position. Many areas occur along this belt where the series is overturned to the west, but the exact angle at which the strata lie is difficult of determination. The orographic thrust producing the folding was directed nearly east and west. Normal faults and overthrusts are indicated, but data for their detection are not now at hand except in one instance.

Whittle[3] describes the pre-Cambrian rocks of Vermont as consisting of two series of Algonkian rocks. The Lower Cambrian quartzite is apparently underlain conformably by the upper of the two, or the Mendon series. That the two are, however, really unconformable is supported, among others, by the following reasons: The extreme lithological diversity of the metamorphic series as compared with the quartzite; a close folding in the Mendon series not observed in the quartzite, and by the fact that the quartzite reposes discordantly upon granitoid gneiss to the southward.

The Mendon series consists in descending order of the following members: mica-schist, with a maximum thickness of 1000 feet; micaceous quartzite, having a maximum thickness of 500 feet and carrying several thin beds of crystalline limestone; crystalline limestone, with a maximum thickness of 400 feet; conglomerate schists and quartzite with a maximum thickness of 700 feet. At Mendon the section has

[1] Mica Deposits in the Laurentian of the Ottawa District, by R. W. ELLS. Bull. Geol. Soc. Am., Vol. 5, pp. 481–488, 1894.

[2] General Structure of the Main Axis of the Green Mountains, by C. L WHITTLE. Am. Jour. Sci., Vol. XLVII., No. 281, pp. 347–354, May, 1894.

[3] The Occurrence of Algonkian Rocks in Vermont and the Evidence for their Subdivision, by C. L. WHITTLE. JOUR. GEOL., Vol. II., No. 4, pp. 396–429, May–June, 1894.

an approximate thickness of 1300 feet, and in some localities there may be 2000 feet of strata in the series.

The lower series of Algonkian, called the Mount Holly series, is contrasted with the Mendon series in nearly every way. The structure of the series is so complicated, the different rock types vary so greatly and the series has been subjected to such a multiplicity of dynamic movements, that no definite stratigraphy has been made out. Some of the prominent rocks of the series are biotite-schist, muscovite-schist, garnetiferous schist, vitreous quartzite, augen-gneiss and various kinds of limestone. The limestones are in irregular lenses, and are extremely local. There may be two horizons of limestone or a dozen. The series, because of the undoubted areas of sedimentary rocks which have escaped destruction, are regarded as clastic. Associated with the above rocks are very abundant schistose, igneous rocks, comprising both dikes and sheets.

The two series of Algonkian rocks are regarded as unconformable for the following reasons: Between the two there is a great lithological difference; the Mount Holly series has been cut through by eruptive rocks in a complicated fashion, and these do not occur in the Mendon series; the Mount Holly series is folded in a much more intricate manner than the Mendon series, and secondary structures have developed to a far greater degree; at the bottom of the Mount Holly series is a widespread formation of conglomerates and gneiss. The schistosity of the two series is parallel, but this is regarded as due to disintegration before the Mendon series was deposited, and to post-Mendon folding.

Smyth, C. H.,[1] gives a petrographical description of the gabbros of the southwestern Adirondack region, and of black hornblende-gneiss which occurs in the same area. The most altered form of the gabbro is very similar to the hornblende-gneiss, and it is suggested that the latter is but an extremely metamorphosed phase of the former.

Smyth, C. H.,[2] describes a group of diabase dikes as breaking through the granite, gneiss and quartzite in the vicinity of the village of Gannanoque, Ontario, the whole being overlain by Potsdam sandstone.

[1] Gabbros in the Southwestern Adirondack Region, by C. H. SMYTH, JR., Am. Jour. Sci., Vol. XLVIII., No. 283, pp. 54–80, July, 1894.

[2] A Group of Diabase Dikes among the Thousand Islands, St. Lawrence River, by C. H. SMYTH, JR. Trans. N. Y. Acad. Sci., Vol. XIII., Sig. 14, pp. 209–214, August, 1884.

Kemp[1] describes the gabbros of the western shore of Lake Champlain. The rocks occurring in this area comprise: (1) gneisses, (2) crystalline limestones, including black hornblendic and pyroxenic schists and gneisses, and (3) anorthosites, including gabbro proper, olivine-gabbros and uorites. The anorthosites over large areas have been profoundly affected by dynamic action, and in many places now have a gneissic structure. In the anorthosites at various places and particularly at Split Rock Mountains, forming the more basic crystallization from the original magma, are lean, titaniferous magnetites which have been mined as iron ores. At the contacts of the gabbro and limestone the latter rock has been bent by dynamic movements; various silicates have developed within it, among which are scapolite, hornblende, pyroxene and titanite. The limestone is also coarsely crystalline. Since the intrusion of the gabbro the limestone has been subjected to dynamic movements, and exhibits strongly the characteristic plasticity of this rock under stress.

Kemp and Hollick[2] find the granite at Mounts Adam and Eve, N. Y., to be intrusive within the limestone. Adjacent to the granites the limestone is white and crystalline and is charged with peculiar contact minerals. This white limestone graduates into blue limestone with transitional graphitic forms. The continuation of this limestone in New Jersey contains Cambrian fossils.

Nason[3] finds as a result of analyses that the white and blue limestone of Sussex county, N. J., are essentially the same in composition, both being magnesian limestones or true dolomites. The coarsely crystalline white limestone near its contact with granite is generally non-magnesian.

Nason[4] gives a summary of facts showing that the white limestone of Sussex county is of Cambrian age, as follows;

[1] Gabbros on the Western Shore of Lake Champlain, by J. F. KEMP, Bull. Geol. Soc. of Am., Vol. V., pp. 213–224.

[2] Granite at Mounts Adam and Eve, Warwick, Orange County, N. Y., and its Contact Phenomena, by J. F. KEMP and ARTHUR HOLLICK, Annals of the New York Acad. Sci., Vol. VII., pp. 638–654.

[3] The Chemical Composition of some of the White Limestones of Sussex County, N. J., by FRANK L. NASON, Am. Geol., Vol. XIII., No. 3, pp. 154–164, March, 1894.

[4] Summary of Facts Proving the Cambrian Age of the White Limestones of Sussex County, New Jersey, by F. L. NASON. Am. Geol., Vol., XIV, No. 3, pp. 161–168, September, 1894.

1. The white limestones are continuous with the blue limestones (now accepted as of Cambrian age) and every degree of transition may be found between them.

2. Both have the same strike and dip.

3. Both are conformable with a quartzite also containing Cambrian fossils.

4. Both are unconformable with the gneiss upon which they rest.

5. Both have in sum total the same chemical composition and are magnesian.

6. The altered crystalline condition of the white limestone is due to the intrusion of igneous masses and to regional metamorphism, while the blue limestone never contains such igneous injections.

7. The presence of certain minerals, especially chondrodite, is not indicative of geological age, as this mineral is known to occur in modern volcanic rocks.

Westgate[1] holds that the crystalline limestones of Warren county, New Jersey, are distinct from and older than the blue Magnesian limestone, and of pre-Cambrian age, for the following reasons: They have a well developed crystalline character, and hold large quantities of accessory metamorphic minerals; they show no intimate association with the blue Cambrian limestones; they show no tendency to grade into them; they have been subjected to general metamorphic forces, of which the neighboring blue limestone shows no trace; they occur in intimate association with the granitoid gneisses, and in some cases appear to be interbedded with them.

Grimsley[2] describes and maps the rocks of a part of Cecil county in northwestern Maryland. The rocks are granite, diorite, and staurolitic mica-schist. The staurolitic mica-schist is regarded as a sedimentary rock. In this the granite-gneiss is intrusive, as shown by the fact that branching dikes and apophyses penetrate the adjoining schists and slates, producing pronounced contact effects upon them. The diorite occurs in dikes in the granite.

C. R. VAN HISE.

[1] The Age of the Crystalline Limestones of Warren County, New Jersey, by L. G. WESTGATE, Am. Geol., Vol. XIV., No. 6, pp. 369-379, December, 1894.

[2] The Granite of Cecil County in Northwestern Maryland, by G. P. GRIMSLEY, Journ. of Cincinnati Soc. Nat. Hist., pp. 50, April and July, 1894.